Machinery Messages

Case History

Catastrophic failure of a cooling tower fan

by Jeffrey A. Marks
Engineer III
Titus Generating Station
Metropolitan Edison
Reading, Pennsylvania

and Glenn Fairchild
Sales Representative
Bently Nevada Corporation

Metropolitan Edison's Titus Station is a power generating facility located south of Reading, Pennsylvania on the Schuylkill River. It has three coal-fired steam generating units, which produce a total of 240 MW of electricity. Titus Station recently had a catastrophic failure on a cooling tower fan that caused them to reevaluate the effectiveness of their manual, walk-around vibration data collection program.

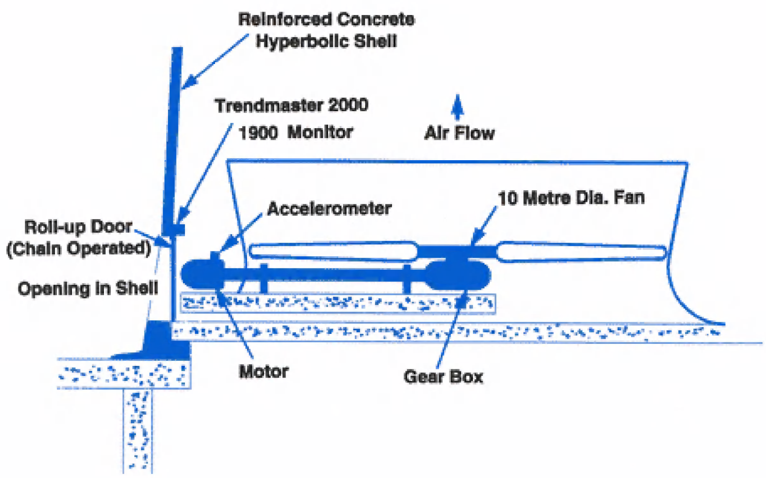
Titus Station uses Bently Nevada systems for both continuous and portable monitoring. A continuous 3300 Monitoring System is installed on one steam turbine, and Titus Station plans to install 3300 Systems on the other two units soon. They have used the portable Bently Nevada Snapshot System to manually collect data on other critical machines since the mid-1980s. Although Titus Station is pleased with the Snapshot, they are aware of the limitations inherent in manual data collection. Data quantity is limited by the availability of trained personnel to take readings. Data quality is dependent on the proficiency of the technician who operates the data collector.

The cooling tower

The mechanical, induced draft cooling tower is a major problem area. The tower is a concrete structure with a hyperbolic shell that is 45 metres (150 feet) tall. Within the hyperbolic shell are eight motor-driven fan assemblies that provide air flow through the tower. Each fan and gearbox is contained within its own fan stack, with the electric motors mounted just outside the stack. A long, horizontal drive shaft that passes through each fan stack couples each electric motor to the input shaft of a right angle gear speed reducer. Each fan is coupled directly to the vertical output shaft of its gear box. Fan motors were monitored once per month using the Snapshot. Since technicians did not have access to the fans and gear reducers that are inside the individual fan stacks, they were not monitored at all.

The nature of a cooling tower makes collecting data with walk-around data collectors difficult. Collecting data from the fan motors require putting on a respirator and entering the cooling tower structure. Severe fog created by the ►

Figures 1 and 2
Destroyed cooling tower fan and gear reducer lying on floor of basin.



Cross section of cooling tower showing fan assembly.

evaporative cooling process sometimes limits visibility to less than a metre. In the winter, ice can form on the walkways between the fan stacks and hyperbolic shell. Because of Titus Station management's concern for its employees' safety, regularly scheduled manual data collection was often delayed for days because of tower conditions. Further delays were caused by lack of manpower during increased station activity.

Titus Station used mechanical vibration switches to protect the fan assemblies from high vibration. A switch was mounted near each electric motor and was wired into its control circuit for automatic shutdown. Plant team members identified two disturbing limitations of the vibration switches. One limitation is that the switch is not located where it can directly monitor the gear reducer and fan. Often, this is where catastrophic failures originate. The switches were mounted on each fan motor, several metres away from each gear reducer and fan. Another limitation is the switch's reliability. The harsh cooling tower environment can damage the switch's internal mechanism, preventing it from shutting down the fan. Also, there is no convenient way to verify that the vibration sensing element is operational. In recent months, vibration switches had failed on at least three occasions to detect increased vibration caused by loose bolts, motor bearing problems, a separating hub and a bent shaft. These limitations prompted team members to intensify the cooling tower walk-around data collection program, as an additional measure to prevent catastrophic failures.

In January 1992, plant personnel working outside the cooling tower heard a loud noise coming from within and notified the station operation department. Operation personnel found that the #2 cooling tower fan, motor and gear box had been completely ripped from their support. The entire fan assembly had fallen into the basin 20 metres (60 feet) below the tower deck (Figures 1 and 2). The portion of the walkway that supported the motor was ripped away, leaving a gaping hole (Figure 3).

Problem analysis

Investigators believe that the failure began when one fan blade sheared off completely, causing significant unbalance. The fan's vibration switch failed to shut it down, and the unbalance forces destroyed it. Investigators found that the switch failed because of corrosion caused by moisture that had entered the casing. This prevented the vibration switch from reacting to the vibration caused by the unbalanced fan.

Figure 3
Fan stack showing a gaping hole where the motor had been.

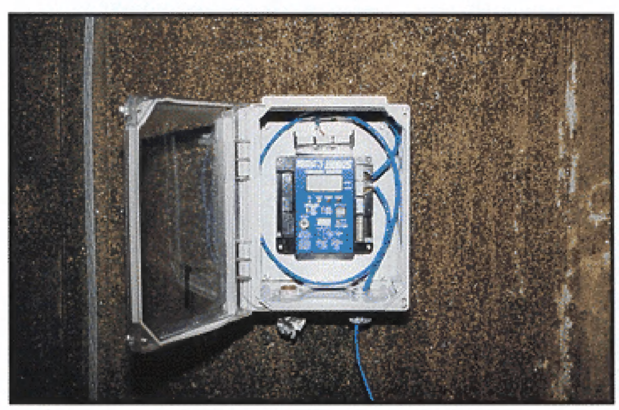


Figure 4
Trendmaster 2000 TIM & 1900 Series Monitor in weatherproof housing, mounted on outer wall of cooling tower.

A team was assembled to investigate the catastrophic failure and recommend solutions to prevent it from occurring again. The team, composed of Titus Station Control Engineers and Performance Engineers, suggested three options:

1. Continue using vibration switches to protect the fans and the Snapshot to manually collect data. Collect data more frequently and periodically test the vibration switches.

   Advantage: Initial hardware costs would be lowest with this option.

   Disadvantage: A technician would have to enter the tower more frequently than before to take vibration readings and test vibration switches. This is unproductive and manpower intensive. Important vibration information might still be missed.
2. Install permanent transducers on the fans, and connect them to monitors that could continuously check the transducers for correct operation. The monitor would automatically shut the fan down if severe vibration was detected.

   Advantage: This would provide a basic, reliable protection system that would preclude a catastrophic fan failure.

   Disadvantage: Initial hardware costs could be substantial. No data would be available for vibration analysis and trending unless a technician entered the tower to take readings. This is again unproductive and manpower intensive.
3. Install permanently-mounted transducers, monitors and an online trending and diagnostic system.

   Advantage: The fans would be protected. Vibration information would be automatically collected and continuously available for trending and diagnostics. It would be possible to detect fan problems at an early stage of development. Technicians would not have to enter the tower to collect data.

   Disadvantage: Initial monitoring system acquisition hardware costs were highest with this option. Some online diagnostic systems require significant training to use them effectively.

Implemented solution

The team estimated that the fan failure and other recent cooling fan problems had cost Titus Station over $300,000. Based on this figure, either the second or the third option could be easily justified. After additional research and cost-benefit analysis, the third option was selected, as it best suited the station's long-term goals.

The team researched various online monitoring and diagnostic systems. They compared the systems' initial hardware and installation costs. They compared the amount of training required to use the systems. They also looked at how easy the systems were to expand, because the station was planning an aggressive predictive maintenance program. The team decided to use an online Bently Nevada Trendmaster® 2000 System with 89129 Low-cost Accelerometers and 1900 Series Monitors. The system was installed on the eight cooling tower fans in early 1994 (Figure 4).

Trendmaster 2000 is a computer-based, online system that automatically samples, processes and trends data for every point in the system. The Trendmaster 2000 System was designed for cost-effective installation, use and expansion. It uses low-cost yet rugged components that are easy to install. Its unique multi-drop architecture allows the installation of up to 256 points on a single cable. A data acquisition computer may have 8 cables with up to 2048 points total. Compared with systems that require an individual wire for each transducer, Trendmaster 2000 is significantly less expensive to install. Expansion often involves just attaching new transducers to existing cables or extending an existing cable to a new location. Little training is required to use Trendmaster 2000's menu-driven software.

The 89129 Accelerometer uses a micro-machined silicon sensor that has the mechanical integrity of an accelerometer at a cost comparable to a velocity transducer. Bently Nevada's 1900 Series Monitors are cost-effective, single-channel, continuous monitors for essential and general-purpose machinery. The 1900 Series Monitors that Titus Station chose have a built-in Trendmaster 2000 interface.

Each cooling tower fan now has two permanently-mounted accelerometers, one on its motor and one on its gear reducer. The accelerometer on each gear reducer is connected to a 1900 Series Monitor, which is configured to shut down the fan on high vibration. All eight 1900 Series Monitors are connected directly to a single Trendmaster 2000 signal cable. The same cable is connected to the accelerometer on each fan's motor through eight Transducer Interface Modules (TIMs). The single cable runs from the cooling tower to the Engineering Room, where it is connected to the online Trendmaster 2000 System computer. Each fan's 1900 Series Monitor and TIM is mounted together in a weatherproof NEMA 4 housing. Each weatherproof housing is mounted on the cooling tower wall near the fan's motor.

Future plans

The Trendmaster 2000 System's design allows for easy expansion. A Trendmaster 2000 Data Acquisition Computer can monitor up to 2048 points. Titus Station plans to expand the system by instrumenting the boiler feed pumps, forced draft fans and induced draft fans. These additions will not only be part of a preventive program but also a predictive maintenance program that will identify machinery problems while they are developing. Early problem identification will save money for both Metropolitan Edison and its customers.

Summary

Walk-around data collectors and mechanical vibration switches may not have the capability to reliably manage cooling tower fan assemblies. Permanent monitors, which provide a "shutdown" function, and a continuous monitoring system with online diagnostic and trending capabilities, may be the best choice to monitor cooling tower fans. This is especially true if cooling towers are operated at or near their designed performance limit, where a loss of cooling capacity could result in a loss of power generation capacity. ■